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Irrigation : Your Water, Your Soil

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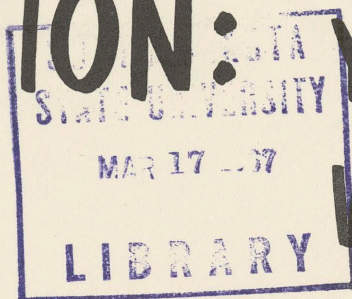
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IRRIGATION: Your WATER, Your SOIL



Interpreting Results of Water and Soil Analyses

Cooperative Extension Service
South Dakota State University, Brookings
United States Department of Agriculture



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IRIGATION:
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Interpreting Results of Water and Soil Analyses

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IRRIGATION: Your WATER, Your SOIL

INTERPRETING RESULTS OF WATER AND SOIL ANALYSES

A THOUSAND, or a hundred years ago, the decision to irrigate a given piece of land with a given source of water was based on physical considerations alone—whether or not the water could be brought to the land, and whether or not crops would grow afterwards. The answer to the more important and long lasting question of how long and how well crops would grow came only as a result of irrigation experience.

Science, technology, and the spread of information have grown tremendously in the last century. There is presently no justification for the use of questionable or unsuitable irrigation waters or land for irrigation. The costs of development and other hazards, including the possibility of early financial stress, demand very careful testing of the soil and water that are to be used. And this must be done before development is begun. Thus, water and soil analyses, prior to a decision to enter upon an irrigation venture, have as their objectives the description of the water and the soil, and the estimation of the compatibility of the soil and the water from the standpoint of growing crops. These estimates must hold not only for the first year, but also for many years to come.

WATER AND WHAT'S IN IT

Let us first consider the water which might be used. Even today, the decision to irrigate is occasionally based only upon the availability of a certain flow or estimated flow from a well or a stream, or some other source. This is a decision based on incomplete consideration and thought. Three distinct hazards may result from use of certain waters for irrigation: (1) the salt hazard, (2) the alkali, or sodium, hazard, and (3) specific toxins or poisons.

The water that will be applied largely determines the quality of the soil moisture with which the plant

oot must be in continuous contact while the plant is alive. Water is the solvent which brings nutrients to the roots and into the plant besides performing many other essential functions. Therefore, the water to be applied to the soil should be relatively low in total soluble salts, low in specific ions which can modify the soil chemically and physically, and low in elements which can be plant poisons.

Table 1 illustrates how the chemist reports the results of his analyses of three water samples to determine suitability for irrigation. Let's look at this report and see how you can evaluate three major factors that are important to the potential irrigator. (See also "Classification of Irrigation Waters" form page 8 (outside back cover).

Salt—Quantity

The total salt content is indicated by two readings in table 1. Reading across from "2," figures show electrical conductivity. This is a measurement of the ability of the water to conduct electrical current. Surface and well waters are composed of water

itself plus various amounts of dissolved salts. Since the amount of salts dissolved in water affects its ability to conduct electricity, the "electrical conductivity" is an index of the overall content of ions or salts present in solution.

Reading across from "3" you find the index of salt content or "total dissolved salts" (TDS) in parts per million (p.p.m.). This indicates the weight in milligrams of dried salt from 1 liter (slightly more than a quart) of the irrigation water and thus gives a weight factor in evaluating the salt hazard. A close correlation exists between electrical conductivity and dissolved salts. These two indicators, then, are the measuring sticks of the total quantity of salt in the irrigation water.

Salt—Kinds

Reading across from "4" and "5" you can see the quantities (in milliequivalents per liter) of sodium, calcium, magnesium, potassium, carbonate, bicarbonate, sulphate and chloride ions, respectively, that have been found by the analyst. Numerous other

Table 1. Results of Analyses of Three Water Samples to Determine Suitability for Irrigation (An Example).

		A	B	C
1	Water Source	Missouri River at Pierre	Grand River at Shadehill	Well Faulk County
2	Elect. Cond. (micro-mhos/cm)	529	2200	5700
3	Total Dissolved Salts (p.p.m.)	343	1320	3640
4	Na Cations Ca (meq/ liter) Mg K	1.87 2.25 1.19 0.09	19.1 3.00 1.70 0.30	17.8 2.17 24.8 0.51
5	Anions CO ₃ (meq/ liter) HCO ₃ SO ₄ Cl	0. 2.52 2.71 0.18	0.6 8.3 16.3 0.30	0 9.99 40.6 10.4
6	Sodium Adsorption Ratio (SAR)	1.4	12.5	3.7
7	Sodium %: Found Possible	35 65	79 98	27 49
8	Residual Sodium Carbonate (meq/liter)	0	4.2	0
9	Irrigation Water Class	Medium Salinity- Low Sodium	High Salinity- High Sodium	Very High Salinity- Medium Sodium
10	Probable Utility in South Dakota, with medium-fine soils	Excellent to Good	Doubtful to Unsuitable	Unsuitable

(See Figure 1 for examples of use of "Classification of Irrigation Waters" form.)

ions exist in greater or lesser amounts in practically all waters, but their content is normally so small as to be of little or no importance agriculturally. Occasionally, nitrate and borates will be found in water, and if they exist in large enough quantities to be toxic to plants or animals, they are extremely important. All salts, whether they be simple like the sodium chloride that we use to flavor our food, or complex, such as a magnesium ammonium phosphate, are composed of these ions, or fragments. These ions have more or less affinity for each other. When the water is separated from them they precipitate out as definite chemical compounds with fixed ratios of the elements contained and with quite definite crystalline structures. Thus, their physical and chemical make-up identifies them as a salt. In water solutions, however, it is impossible for the chemist to identify all possible combinations which might exist without a great deal of time and effort. Therefore, he identifies and measures the various ions which are contained in the solution.

The importance of the total soluble salt content has been indicated in the previous section. The salt quality, or ratios of the ion constituents, is another factor in the quality of water which is extremely important to the success of irrigation. Most important among these is the ratio of sodium to the total of calcium plus magnesium. The ions determined by the chemist are reported in the analysis as milliequivalents per liter. The ratio of sodium to calcium plus magnesium, then, is on a chemical equivalent basis. This ratio is usually expressed as the "soluble sodium percentage," which is simply sodium divided by the total of calcium, potassium, magnesium plus sodium and multiplied by 100 (read across from "7"). A slightly more sensitive index of the sodium factor is given by the "sodium adsorption ratio"* (across from "6"). Both values are a measure of the tendency for buildup of sodium in soil clays. As will be explained later, this is a hazard which must be constantly guarded against during irrigation planning and operation.

Further indices of the sodium hazard of the water are to be seen across from "7". These are the "possible sodium percentage" (that fraction of cations which would be sodium if the calcium and magnesium are precipitated by carbonate and bicarbonate present), and, across from "8," the "residual sodium carbonate," the sodium which would be associated with carbonate and bicarbonate ions if all calcium and magnesium are precipitated when

it becomes the soil solution. These indices must be evaluated by the analyst.

Specific Toxic Elements

The third general hazard which the analyst as well as the farmer and the irrigation planner must be aware of is the possibility of a specific poison being present in the water. This includes boron and other elements having specific toxicity to crop growth when present in certain concentrations. However, the boron content in South Dakota waters is generally much below the minimum which will cause bad effects among crop plants.

INTERPRETING THE ANALYSIS

Figure 1 (outside back cover) shows a diagram adapted from the U. S. Salinity Laboratory Handbook No. 60 which is used by analysts to record the general classification of irrigation waters and the possible hazards presented to agriculture by waters of various qualities. This form is similar to the one used by the Water Quality Laboratory at Brookings.

Look at the bottom of the diagram first. Note that the electrical conductivity (total salt index) of water is divided into four categories, 100-250, 250-750, 750-2,250, and that above 2,250. These four categories represent classes 1, 2, 3, and 4 of salinity or total salt hazard to the soil. This is entirely separate from the alkali or sodium hazard, and this must be kept in mind at all times in discussing and evaluating irrigation waters. The four salinity hazards are low, medium, high and very high. The reason for considerable range within each of these groups is that conditions of natural precipitation and internal drainage of the soil may modify the effect of a given kind of water on the salt buildup in the soil. Therefore, in estimating the probable success or failure of an irrigation venture with water of questionable quality the analyst or the irrigation planner must use judgment and knowledge of soil, climate, time of year in which irrigation will likely be done, total water requirement by the crop, plus other similar factors.

The left side of the chart shows that the sodium or alkali hazard is also divided into four categories—low, medium, high, and very high. These four categories denote the salt-kind hazard to the soil. The *water quality criterion* used in making the subdivisions is the *sodium adsorption ratio*, a mathematical expression mentioned earlier, which denotes the tendency of the water to impart sodium to the clay complex of the soil. The accumulation of the sodium ion in the clay minerals is a major cause of the destruction of the structural units of the soil. Water with a sodium adsorption ratio of less than 10 is considered low in its alkali hazard as long as

$$\text{*Sodium Adsorption Ratio} = \frac{\text{Na}}{\sqrt{\frac{\text{Ca} + \text{Mg}}{2}}}$$

the electrical conductivity or total salt content is low, or even medium. But when the salt content gets to be high or very high, water of a sodium adsorption ratio of 10 is quite hazardous as to the buildup of sodium in the clay complex. For this reason, the lines dividing the various classes of alkali hazard are drawn on a diagonal slanting downwards to the right, indicating the increased danger of a certain ratio of sodium to calcium plus magnesium as the total salt content of the water increases. The chart is used properly by reading across (conductivity) and up (sodium adsorption ratio).

We have considered briefly the three types of hazards which may bring on problems because of the salts carried in irrigation water. They are the salinity or salt problem itself; the alkali or sodium problem, with the possibility of dispersion of clays; and lastly, the specific poison problem, which in most cases would be boron. Inasmuch as boron is low in practically all South Dakota waters, there will be no further consideration of this problem.

Line 10 of table 1 states the probable sustained utility of these waters in South Dakota on medium-fine soils.

THE SOIL—THE HOME OF THE PLANT

Let us consider briefly the soil to which the water is to be applied. The soil is the home, the physical anchor, the source of nutrients, the air supply to roots, and the water supply to the crop that you will grow. Therefore, the environment the soil presents to plant roots, physically and chemically, must be compatible with the needs of the crops in order that rapid growth and profitable farming may result.

No part of nature is extremely simple, and the soil is a complex, organized system which must sustain biological activity both on the micro scale and on the economic plant scale for it to be of use to man. There will be no attempt in this publication to discuss all of the factors about soil which are important to plant growth, but a few of the major ones will be mentioned briefly.

Texture

Texture is related to content of the fine, medium and coarse particles, referred to generally as clay, silt and sand. Texture imparts to the soil its general behavior; water intake rate, water retention and movement through the soil, aeration, stickiness, ease of tillage, density, and many other physical features observable by man. The texture of soil can be determined only by laboratory separation of sand, silt, and clay after adequate dispersion of aggregates. It can be estimated, however, by an experienced field

man or technician by the feel of the soil, its behavior at certain moisture contents, and other field-observable qualities.

Structure

Structure is the organization of the clay, silt and sand particles into larger units which can be discerned with the eye. These larger units called aggregates, crumbs, blocks, platelets, columns, etc., are nature's way of organizing the soil so that air and water may move into and through the soil and crops may grow. The structure is largely a function of two fundamental characteristics of the soil. First, the organic matter and the frequency of renewal of organic matter; and secondly, the relative content of sodium as compared to calcium, magnesium and other ions in the clay complex. This is not the same as the salt content of the soil, although it is related to it. Certain salt constituents such as the sodium ion tend to impart to the colloids a tendency to disperse from one another, resulting in the break-up of aggregates and the behavior of the soil as a mass without structure. The true alkali soils have an unfavorable ratio of sodium to calcium and magnesium in the clay or cation exchange complex, and this is generally the cause of their unfavorable physical condition. Adobe silts and clays and "gumbo" soils behave similarly, but usually for a different reason.

Organic Matter

The organic matter which is present at any given time in the soil, and the frequency with which organic matter is replenished by crop rotations, by grass and other materials incorporated in the soil, are extremely important features to agriculture. They have a great deal to do with the physical behavior of the soil, as well as its fertility.

Depth

The depth of soil determines the total volume which is available for plant root exploitation, the removal of water and plant nutrients. The deeper the soil, generally, the more productive it is.

Fertility

The fertility of the soil is its ability to hold in available form and release to crops the essential elements of plant growth, and is related to its clay and silt content, the nature of the parent materials and clay minerals and the organic matter content.

Salinity

Soluble salts commonly present in soils include sodium chloride, sodium sulphate, magnesium sulphate, calcium chloride, calcium sulphate and many others. Salinity is commonly measured by the electrical conductivity of a water extract. The greater the salt content of a soil the less the availability of

the water and the greater the chance of toxic effect on plant roots. Salinity may be derived from soil parent material, seepage water, or irrigation water. Salt in mature soils generally reflects poor internal drainage and may indicate a fluctuating or high water table.

Alkali

The term “alkali” is widely used to indicate salt content, and there is much confusion as a result. In accurate use, however, “alkali” should denote only the relative content of the sodium ion in the clay complex, and therefore the physical behavior of the clay should be reflected by the alkali situation. The alkali factor of soils is generally reported and used over the United States and many other parts of the world as “the exchangeable sodium percentage.” This means the fraction of the clay’s capacity to hold cations in exchangeable form which is occupied by sodium. Even as a water softener holds exchangeable sodium to trade for the calcium and magnesium of the hard water which enters it, and to release a sodium water which we call “soft,” so also does the soil have a great reservoir of exchangeable calcium and magnesium or calcium and magnesium and sodium. When the sodium ion becomes more than 15% of the exchangeable cations present in the soil reservoir, we classify the soil as an “alkali” soil.

The following table gives the classification of salt affected soils and the limits of salts and sodium which are presently regarded as the boundaries of each class.

Soil Classification	Salinity: Electrical Conductivity Saturation Extr.	Alkali: % Exchangeable Sodium in Colloid Complex
Normal	less than 4 m mhos per cm	less than 15
Saline	greater than 4	less than 15
Alkali	less than 4	greater than 15
Saline-Alkali	greater than 4	greater than 15

Note that a normal soil has less than 4 m mhos/cm of electrical conductivity in the water extract and less than 15% exchangeable sodium in the clay complex. A saline, or salty, soil has an increased electrical conductivity but still less than 15% exchangeable sodium in the colloid complex. The alkali soil, on the other hand, will have a lower electrical conductivity, or salt content, but more than 15% exchangeable sodium in the clay complex. The saline-alkali soil is both salty and high in sodium in the clay, having greater conductivity than 4 and greater than 15% exchangeable sodium.

Specific Toxic Factors

Occasionally there will be a specific toxic factor in a soil, as in some of the soils of the Imperial

Valley in California containing large quantities of boron. Boron is essential to plant life in small quantities, but poisonous in quantities above 3-4 parts per million. In South Dakota soils, it is relatively uncommon to find more than 2 p.p.m. of boron; consequently, we have no boron problem. However, there may be other elements (for example manganese and selenium) soluble in toxic quantities in certain soils.

Interpretation And The Important Decision

The interpretation of the results and the decision must be more than simply following results of analyses to a point in a diagram and deciding whether or not a water has a high, medium or low sodium hazard, and a high, medium, or low salt hazard, and whether a soil is presently normal, saline, alkali, or saline-alkali. An intelligent decision must be based on the knowledge of these mechanical factors plus the interpretation of the effect of the kind of agriculture that will be undertaken, the nature of the soil and its parent material, the substratum and its facility for moving water, or the all-important question of internal drainage, the amount of natural precipitation received and the period of the year in which it comes, and many other physical and somewhat intangible factors.

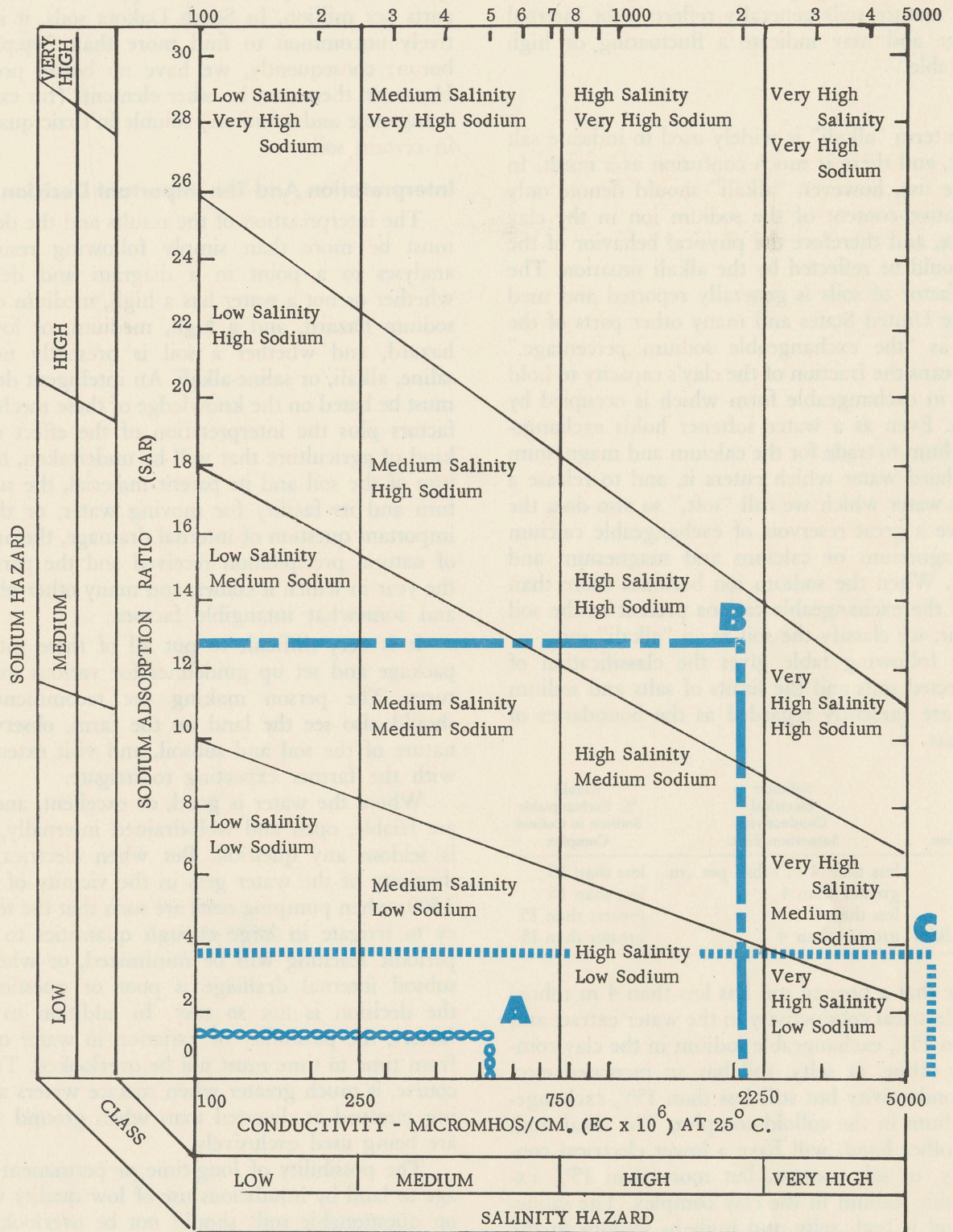
It is very difficult to put all of these into one package and set up guidelines for various soil textures. The person making the recommendation should also see the land on the farm, observe the nature of the soil and subsoil, and visit extensively with the farmer expecting to irrigate.

Where the water is good, or excellent, and soils are friable, open and well-drained internally, there is seldom any question. But when electrical conductivity of the water gets in the vicinity of 2,500-3,500; when pumping costs are such that the tendency to irrigate in large enough quantities to cause periodic leaching will be minimized, or when the subsoil internal drainage is poor or questionable, the decision is not so easy. In addition to these factors, the possibility of variation in water quality from time to time must not be overlooked. This, of course, is much greater when surface waters are being pumped or diverted than when ground waters are being used exclusively.

The possibility of long-time or permanent damage to land by injudicious use of low quality waters on questionable soils should not be overlooked by any potential irrigator in South Dakota. The decision to irrigate should be made with full knowledge of all of the quality factors of water and soil which can be learned and with a good judgment evaluation of the many factors involved besides the soil and the water itself.

Figure 1. Classification of Irrigation Waters*

(Note: Examples from Table 1 on page 4 are shown in blue.)



Electrical Conductivity

A=529; B=2,200; C= 5,700

Sodium Adsorption Ratio

A=1.4; B=12.5; C=3.7

*Adapted From Agricultural Handbook 60, USDA